

It is also shown that there should be significant reduction of both co- and adjacent-channel interference caused by **POWER-side** signals.

A number of on-the-air evaluations of the system support the results of the above analysis, including the reduction of selective fading and reduction of co- and adjacent-channel interference effects.

The advantages of the system were separated into two types: one group applicable only to mono receivers capable of "Sideband Tuning"; and a second group of advantages that are available to all types of receivers, including carrier or center-tuned mono and stereo radios.

## APPENDIX A

### Analysis of Co-Channel "Sideband Beat"

The amplitude of the "Sideband Beat" of a co-channel interfering signal is a function of the relative amplitudes of the interfering wave and the desired wave. Under practical operating conditions, the desired signal is at least 20 db greater than the interfering co-channel wave. Accordingly, the envelope-detector performance closely approximates the performance of a product-type detector in that the strong local carrier controls the "switching function" of the envelope detector. (Communication engineers will recognize the similarity of this operation to "exalted carrier" detection which was used in early short wave SSB receivers.)

As pointed out above, the phase of the local carrier, relative to the interfering carrier, is a function of time, and under typical conditions the angle between the two carriers is an unbiased random function, i.e., a rectangular density function.

When there is a specific frequency difference between the two carriers; for example, a 1 Hz error, the beat frequency will equal 2 Hz (two times the carrier difference frequency<sup>10</sup>),  $\pm$ two times the random frequency errors that would even apply to a phase-locked "synchronous" stations. Such random frequency errors are functions of propagation characteristics, receiver location, etc.

As mentioned above, the most important phenomenon in terms of co-channel interference is the dramatic variation in audio level of the undesired signal as the angle between the two carriers swing over a cycle. When this angle reaches 90 degrees, or any other odd multiple of 90 degrees, the amplitude of the fundamental Fourier component is nulled, leaving a slight amount of second harmonic distortion. (The reason the distortion is small is that the desired carrier causes the envelope detector to approximate the action of a product demodulator, greatly reducing the quadrature distortion effect.)

It is useful to determine the amplitude for the complete range of relative carrier phase between the desired and undesired signals over a 0 to  $\pm 90$  degree region. (At angles beyond  $\pm 90$  degrees the amplitude repeats this same shape.)

In the following equations the RF terms, DC terms, and the sub-audible low frequency terms generated by beating the two carrier frequencies are deleted. Thus, the analysis can be restricted to multiplying the local carrier by the two co-channel interference sidebands. It is assumed that the sidebands from the co-channel interfering signal are produced by a single-tone modulation and with a modulation factor of  $m$ . It is also assumed that the local station's carrier has an amplitude of  $K$  volts and the interfering carrier has an amplitude of unity.

$$e = \underbrace{[1 + m \cos(\omega_A t)]}_{\text{Interference}} \times \cos(\omega_c t) \times \underbrace{K \cos(\omega_c t + \theta)}_{\text{Local Carrier}}$$

Ignoring interfering carrier

$$= \left[ \frac{m}{2} \times \cos(\omega_c t + \omega_A t) + \frac{m}{2} \times \cos(\omega_c t - \omega_A t) \right] \times K \cos(\omega_c t + \theta)$$

Using product trigonometric identities

$$= K \frac{m}{4} \times \cos(\omega_A t - \theta) + K \frac{m}{4} \times \cos(2\omega_c t + \omega_A t + \theta) + K \frac{m}{4} \times \cos(-\omega_A t - \theta) + K \frac{m}{4} \times \cos(2\omega_c t - \omega_A t + \theta)$$

Considering only audio components

$$e = K \frac{m}{4} \times \cos(\omega_A t - \theta) + K \frac{m}{4} \times \cos(\omega_A t + \theta)$$

noting  $\cos(\theta) = \cos(-\theta)$

Using the following identity:

$$\frac{1}{2} [\cos(A-B) + \cos(A+B)] = \cos A \times \cos B$$

We see that:

$$e = \cos \theta \times K \frac{m}{2} \times \cos(\omega_A t)$$

Thus, the amplitude of the sideband beat wave follows the absolute value of a cosine wave, which is a well known waveshape in radio engineering; i.e., the output of a resistance-loaded full-wave rectifier.

## APPENDIX B

### Analysis of "Weak Platform Motion"

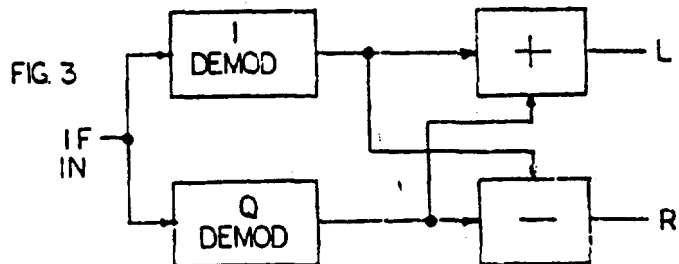


FIG. 3 is a simplified block diagram of a phase separated type AM Stereo decoder. It does not include distortion correction circuitry, as would be required for the Magnavox or Motorola type AM Stereo decoder. (Since the Harris system is a true quadrature system it does not require any distortion correction circuitry.)

Assuming that the receiver is tuned to a strong local signal, which at the instant of analysis is unmodulated, the waveshapes of FIG. 4 show how a conventional AM wave will exhibit severe image notion when demodulated by a phase separated type decoder.

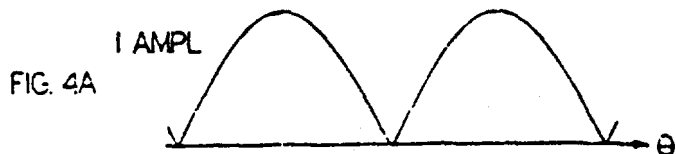


FIG. 4a shows the amplitude of the in-phase audio wave as a function of the phase between the strong local carrier and the weak interfering co-channel carrier. This waveshape has been discussed in Appendix A.

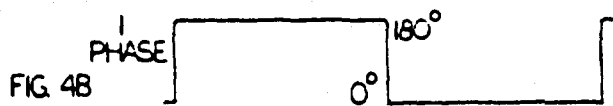


FIG. 4b shows the phase of the in-phase component. It is seen that the demodulated audio reverses phase whenever the amplitude function goes through a cusp.



FIG. 4c shows the amplitude function of the quadrature component of the incoming interfering wave.

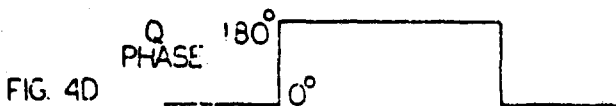


FIG. 4d shows the phase function of the quadrature audio wave.

Under normal operating conditions, the outputs of the I and Q detector of FIG. 3 are combined in the sum-and-difference matrix, producing the desired L and R waves. Unfortunately, the interference from the weak co-channel station swings from full left, to center, to full right, as a function of carrier phase. This is shown in FIG. 4e.

IMAGE LOCATION RIGHT CENTER LEFT CENTER RIGHT CENTER LEFT CENTER  
FIG. 4E

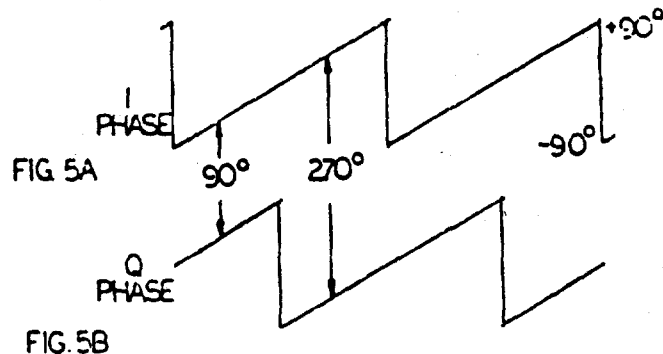
The reason the wave falls in the center at regular intervals is that at those instances either the I amplitude is zero or the Q amplitude is zero. Under such conditions, since there is only one signal going into the sum-and-difference circuits, the L and R outputs must be equal, causing the image to appear in the center. (When the phase of the L and R outputs are out of phase as they are when the I amplitude is zero, the image will be somewhat strange, as it is with any out-of-phase speaker situation.)

During other conditions of carrier phase, the left and right channels are unequal. Complete separation points will occur when the amplitude of the I wave and the amplitude of the Q waves are equal. In other words, at multiples of 45 degrees between the two carriers the I and Q detector outputs are equal. Since at these instances the I and Q audio signals are either in phase or out of phase, either a full L signal results or a full R.

This simple analysis clearly shows how an interfering co-channel AM wave causes "Weak Platform Motion". Such Platform Motion has been experienced in the field and it results in significantly increased annoyance by causing, in effect, the interference to "wave" at the listener.

Now, let us consider FIG. 5 which shows the phase function of a pure SSB wave. While the *POWER-side* wave is not a pure SSB wave, it should substantially reduce Weak Platform Motion.

In the case of the SSB wave, the amplitude of the I and Q waves are equal under all phase conditions. This is one of the basic reasons why SSB reception is particularly rugged, in terms of providing acceptable performance under disturbed propagation conditions. The phase of the I and Q audio waves linearly swing from  $-90$  degrees to  $+90$  degrees. (This assumes the upper sideband is transmitted. If the lower sideband is transmitted the phase slopes are reversed.)



Examination of FIGS. 5A and 5B shows the phase difference between the I and Q audio waves is either 90 or 270 degrees. This causes the L and R outputs of FIG. 3 to be equal because the I and Q waves are equal in amplitude and are in quadrature. Thus, under all conditions of relative carrier phase, the L and R waves are equal and the interference will remain in the center, eliminating this one form of Platform Motion.

Unfortunately, the more serious "Strong Platform Motion" is caused by self interference, and there is no apparent mechanism for removing it.

## NOTES

1 Leonard R. Kahn, *Compatible Single-Sideband*, Proc. IRE, Vol. 49, No. 10, pp 1503-1527. Also see earlier forms of sideband broadcasting: N. Koomans *Asymmetrical sideband Broadcasting*, Proc. IRE, Vol. 27, pp 687-690, and P.P. Eckersly *Asymmetrical-sideband Broadcasting*, Proc. IRE Vol. 16, pp 1041-1092.

2 Private communication from Dennis R. Ciapura, Vice President, Noble Broadcasting Co. to Leonard R. Kahn, describing special stereo processing used by the recording industry.

3 Leonard R. Kahn, *Amplitude Modulation Theory and Measurements - New and Old Paradoxes*, Proc. 41st NAB Annual Broadcast Engineering Conf. 1987.

4 Synchronous demodulators multiply the carrier components by the sidebands; they also have been called "product demodulators" and "exalted carrier detectors". Synchronous demodulators do, however, eliminate the distortion of an envelope detector when detecting a conventional AM wave suffering from selective phase distortion.

5 Experimental verification first obtained by radio station KSL - Bonneville, engineering department.

6 Experimental verification obtained by radio station WELI - Clear Channel engineering department.

7 The author points out that while there has been no experimental verification, the analysis indicates that there should be some reduction of "Weak Platform Motion." Recognizing the commercial importance of this matter, it is believed that early publication of this particular facet of the *POWER-side* system, absent experimental proof, is justified. The author plans to write a further article covering these effects as well as information concerning methods for enhancing stereo effects when *POWER-side* signals are received with Kahn Hazeltine type AM stereo radios.

8 D.L. Bordonaro, *WFTQ Occupied Spectrum Kahn STR-84*, dated February 26, 1986.

9 Private communication between Mr. Andy Laird, Vice President of Engineering for Heritage Media Corporation (KDAY), and Leonard R. Kahn.

10 The reason for the doubling of the error  $\Delta F$  is that the carrier error displaces the audio from one sideband by  $+\Delta F$ , and the audio from the other sideband audio by  $-\Delta F$ , making the difference between the two audio waves  $2\Delta F$ .

CERTIFICATE OF SERVICE

I hereby certify that I have caused to be mailed by Express Mail, Next Day Delivery this day copies of the foregoing Reply Comments and the confidential appendix thereto to:

Michael Menius, Esq.  
Motorola, Inc.  
1350 Eye Street, NW, #400  
Washington, D.C. 20005

I hereby certify that I have caused to be mailed by prepaid first class mail the foregoing Reply Comments, but without the confidential appendix, to:

Donald G. Everist  
Cohen, Dinnell & Everist

Roger Goodspeed, Esq.  
Capital Cities/ABC, Inc.

James Dorrence  
2223 Florey Lane  
Arlington Twp., PA 19001

Communications Technologies, Inc.  
P.O. Box 1130  
Marlton, NJ 08053

David H. Solinske  
877 Executive Dr., W.#300  
St. Petersburg, FL 33702

John J. Tibilietti  
Route 9, Box 143  
Victoria, TX 77901

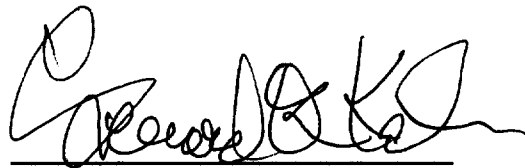
Communications Technologies, Inc.  
P.O. Box 1130  
Marlton, NJ 08053

Carle Place, New York  
April 19, 1993

Philip E. Galasso  
131 Stafford Forge Road  
West Creek, NJ 08092

Burt Sherwood  
4171 Dundee Rd., Ste. 269  
Northbrook, IL 60062

Peter Kraushar  
13275 SW Berthold St.  
Beaverton, OR 97005

A handwritten signature in dark ink, appearing to read 'Leonard R. Kahn', written over a horizontal line.

Leonard R. Kahn